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REMOTE SENSING RECONNAISSANCE OF  
FAULTING IN ALLUVIUM, LAKE MEAD TO LAKE HAVASU,  
CALIFORNIA, NEVADA AND ARIZONA

An Application of ERTS-1 Satellite Imagery

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An Application of ERTS-1 Satellite Imagery

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ABSTRACT

Analysis of ERTS-1 MSS and other imagery for a 125 x 25 mile area in the southern part of the Basin-Range Province of southeastern California, southern Nevada and northwestern Arizona, indicates the presence of numerous color and contrast anomalies in alluvium. Field work guided by high altitude U-2 and Side Looking Aerial Radar imagery confirmed that these anomalies are fault zones, many of which are believed to be of Recent age. Few faults in alluvium have been reported from previous ground based geologic studies in the area.

Some faults occur along range fronts where they have been traced along strike into bedrock but more often they are found out from the range fronts in the intermontane alluvial sediments. The faults strike generally northward and have predominantly dip slip displacement. Many bound grabens suggesting an east-west direction of extension. Major extension occurred in this area during a mid-Tertiary episode of plutonism, volcanism and normal faulting.

ERTS imagery provides a synoptic perspective previously unavailable for regional geologic studies. The ability to conduct rapid and inexpensive reconnaissance of Recent faulting has important applications to land use planning, ground water exploration, geologic hazards study and the siting and design of engineering projects.

## INTRODUCTION

Analysis of Earth Resources Technology Satellite (ERTS-1) multispectral scanner (MSS) imagery and subsequent field study indicates the presence of numerous faults cutting alluvium in an area approximately 125 miles long and 25 miles wide (Fig. 1). The area lies between 34°-15'N and 36°-45'N and 114°W to 115°W in the southern part of the Basin-Range Province.

### Method:

The widespread development of normal faults in Late Tertiary and Quaternary alluvium was recognized by study of anomalies present in ERTS and Apollo space imagery. Details and individual breaks were mapped using available color infrared and black and white U-2 imagery and SLAR. Another important tool in directing field study was the use of 35mm color transparencies taken during low altitude fixed wing reconnaissance. Imagery used in this study is listed below:

|            |                                     |
|------------|-------------------------------------|
| ERTS-1 MSS | 12 September 1972, Frame 1069-17432 |
|            | 5 November 1972, Frame 1105-17443   |
|            | 6 November 1973, Frame 1106-17495   |

|          |                                      |
|----------|--------------------------------------|
| Apollo 9 | Frames AS 9-20-3135 and AS 9-20-3136 |
|----------|--------------------------------------|

|  |
|--|
| Side Looking Aerial Radar, Westinghouse AN/APQ 97 XE-1,<br>NASA Mission 103, 5 November 1965 |
|--|

U-2 High Altitude Photography, USAF-USGS (Black and White):

Mission 018V, 10 July 1968, Frames 211 through 214

Mission 018L, 10 July 1968, Frames 214 through 217

Mission 059V, 17 July 1968, Frames 169 through 174,  
177, and 178

Mission 059R, 17 July 1968, Frames 164 through 178

Mission 374V, 6 September 1968, Frames 209, 211  
212, 213 and 214

Mission 374L, 6 September 1968, Frames 208 and 209.

NASA U-2 High Altitude Color IR Photography, Mission 189.

### Background:

Some faults in alluvium, not shown in our illustrations, have been mapped by previous workers. Willis Lee (1908) shows an extension of the Grand Wash Fault for a short distance into alluvium in Hualpai Valley east of Detrital Valley.

Longwell (1936) shows two faults which extend through volcanics and for short distances into alluvium near Echo Wash in an area now covered by the Overton Arm of Lake Mead. Another fault mapped by Longwell cuts recent gravel and wash deposits about four miles north of Hoover Dam at the south end of Lake Mead. In a later paper, Longwell (1963) describes a basin in which alluvium was being deposited while the basin was lowered along the Horse Thief Fault two miles east of Hoover Dam. Longwell also mapped several faults in alluvium along the Colorado River south of Lake Mead, the largest of which is now covered by Lake Mojave. Hansen (1962) shows a small normal fault which strikes approximately north-south along the west side of the Colorado River about 15 miles north of Lake Mojave. The abundance of late Quaternary faulting has not been generally recognized.

## RESEARCH

### General Characteristics:

Fault scarps recognized in our investigation are shown in Figures 2 and 3. Some faults occupying range front positions have been traced from breaks in alluvium into bedrock. Most faults, however, occur well out from the range fronts in the alluvium. These faults are generally characterized by long, sharp, linear breaks in slope, parallel alignment, and frequent juxtaposition of contrasting alluvial sediments. The youngest faults disrupt the drainage texture and are only beginning to be incised by intermittent streams. The traces of older faults are frequently apparent as a contrast in alluvial rock type or drainage texture, although their original topographic expression may have become indistinguishable. No evidence of landslide morphology is recognized, associated with the scarps.

### Fault Description:

In ERTS imagery, a light colored zone in alluvium extends from the bend in the Colorado River near Bullhead City, Arizona south-southeast toward Topock, Arizona. Field study indicates that this zone is made up of light colored sandy sediments, bound on the west by a west dipping escarpment 15-25 feet high, which we interpret as a normal fault (Figure 2). South of Topock and along the east shore of Lake Havasu, a possible extension of this fault has been recognized. The fault is thought to extend northward into bedrock in the Newberry Mountains west of Bullhead City where it has been mapped independently by one of the authors and by Alexis Volborth (personal communication). Here this fault cuts Precambrian augen gneiss and Tertiary granitic rocks along an intensely brecciated zone up to one half mile wide (Figure 2).

The largest number of faults in alluvium were found west of Gold Butte and east of the Overton Arm of Lake Mead (Figure 3). Field study guided by color infrared

U-2 imagery provided detail on the system of scarps in this area. Several well developed grabens bound by normal faults are present in the alluvium, as well as other generally north trending normal faults. These faults indicate structural extension in an east-west direction. Dikes south of Lake Mead which cut Quaternary alluvium follow this northerly trend, as do the major range front scarps in the region. Two weakly defined faults may extend in an anomalous northeast direction in this area with possible left lateral offset of washes along them.

#### Regional Significance:

The area between Lake Mead and Lake Havasu was the site of extensive mid-Tertiary volcanism and related plutonism. Dike swarms elongated plutons, and penecontemporaneous normal faulting all maintain a generally northerly trend (Bechtold and Others, 1972). These phenomena are believed to represent crustal extension on the order of several tens of miles. The mechanisms of crustal extension are well documented for key areas within this province. Anderson (1971) describes complex systems of low angle normal faults in the Nelson area, Nevada, which he believes resulted during distension of thick volcanic cover during rifting and emplacement of plutons at depth. Volborth (personal communication, 1972) describes mid-Tertiary extensional emplacement of plutons and dike swarms in the Newberry and Eldorado Mountains west of the Colorado River and south of Lake Mead.

The orientation and abundance of normal faults cutting alluvium shown in Figures 2 and 3 suggest that regional structural extension has occurred during late Pleistocene and Recent Time. Similar extensional normal faulting has been recognized in other parts of the Basin-Range Province. (Stewart, 1971, Thompson, 1967).

#### Implications:

The ERTS-1 multispectral scanner imagery has provided an effective tool for geologic reconnaissance of fault breaks in unconsolidated alluvium over an area of several thousand square miles. Intermediate scale U-2 photography and side looking aerial radar guided field study and provided detail for mapping, but most fault zones could be distinguished as contrast or color anomalies in ERTS-MSS imagery. Few of these faults have been reported on the basis of previous conventional geologic mapping, nor would the regional extent and consistent orientation have been obvious from maps of small sub-areas.

The ability to conduct low cost regional surveys of recent faulting has several important applications. The distribution of recent fault breaks should be seriously considered in regional land use planning. This is especially significant in determining the location and engineering design of installations such as dams, highway

systems, and nuclear generating stations. We are presently corresponding with other workers studying microseismic activity in the Lake Mead area in order to compare surface break distribution with present and historical earthquake activity.

Many alluvial fault breaks form suitable traps for ground water. Reconnaissance mapping of faults guided by ERTS imagery may provide an important tool for hydrologic exploration in arid terrain.

## REFERENCES

- Anderson, R. E., 1971, Thin Skin Distension in Tertiary Rocks of Southeastern Nevada: Geol. Soc. America Bull., v. 82, p 43-58.
- Bechtold, I. C., Liggett, M. A., and Childs, J. F., 1972, Structurally Controlled Dike Swarms Along the Colorado River, Northwestern Arizona and Southern Nevada (ABS): NASA-CR-128290, E72-10192.
- Hansen, S. M., 1962, The Geology of the Eldorado Mining District, Clark County, Nevada: Ph.D. Thesis, University of Missouri, Rolla, Missouri
- Lee, W. T., 1908, Geologic Reconnaissance of a Part of Western Arizona: U.S. Geol. Survey Bull. 352, 96 p.
- Longwell, C. R., 1936, Geology of the Boulder Reservoir Floor, Arizona-Nevada: Geol. Soc. America Bull., Vol. 47, p. 1393-1476.
- Longwell, C. R., 1963, Reconnaissance Geology Between Lake Mead and Davis Dam, Arizona-Nevada: U.S. Geol. Survey Prof. Paper 374.E, 51 p.
- Stewart, J. H., 1971, Basin and Range Structure: A System of Horsts and Grabens Produced by Deep-Seated Extension: Geol. Soc. America Bull., v. 82, p 1019-1044.
- Thompson, G. A., 1967, Background and Results: in Geophysical Study of Basin-Range Structure, Dixie Valley Region, Nevada (G. A. Thompson and Others), U.S. Air Force, Cambridge Res. Labs., Final Rep.
- Volborth, A., 1972. Personal Communication  
Nevada Bureau of Mines, Reno, Nevada.

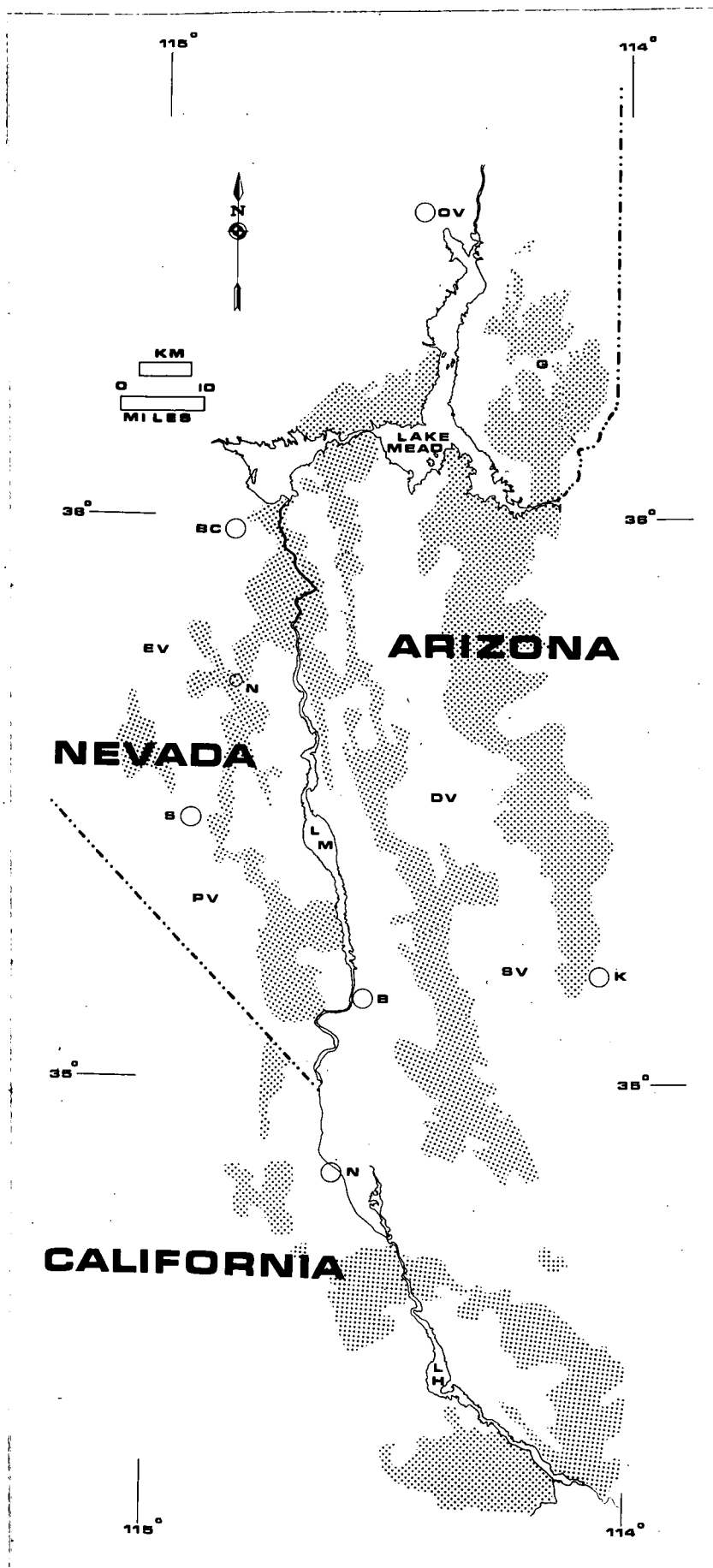


Figure 1

Index map of the area from Lake Mead to Lake Havasu in southeastern California, northwestern Arizona and southern Nevada. Bedrock areas are shaded.

Location Index

- B Bullhead City, Ariz.
- BC Boulder City, Nev.
- DV Detrital Valley, Ariz.
- EV Eldorado Valley, Nev.
- G Gold Butte, Nev.
- K Kingman, Ariz.
- LH Lake Havasu
- LM Lake Mojave
- OV Overton, Nev.
- N Needles, Calif.
- N Nelson, Nev.
- PV Piute Valley, Calif.-Nev.
- S Searchlight, Nev.
- SV Sacramento Valley, Ariz.



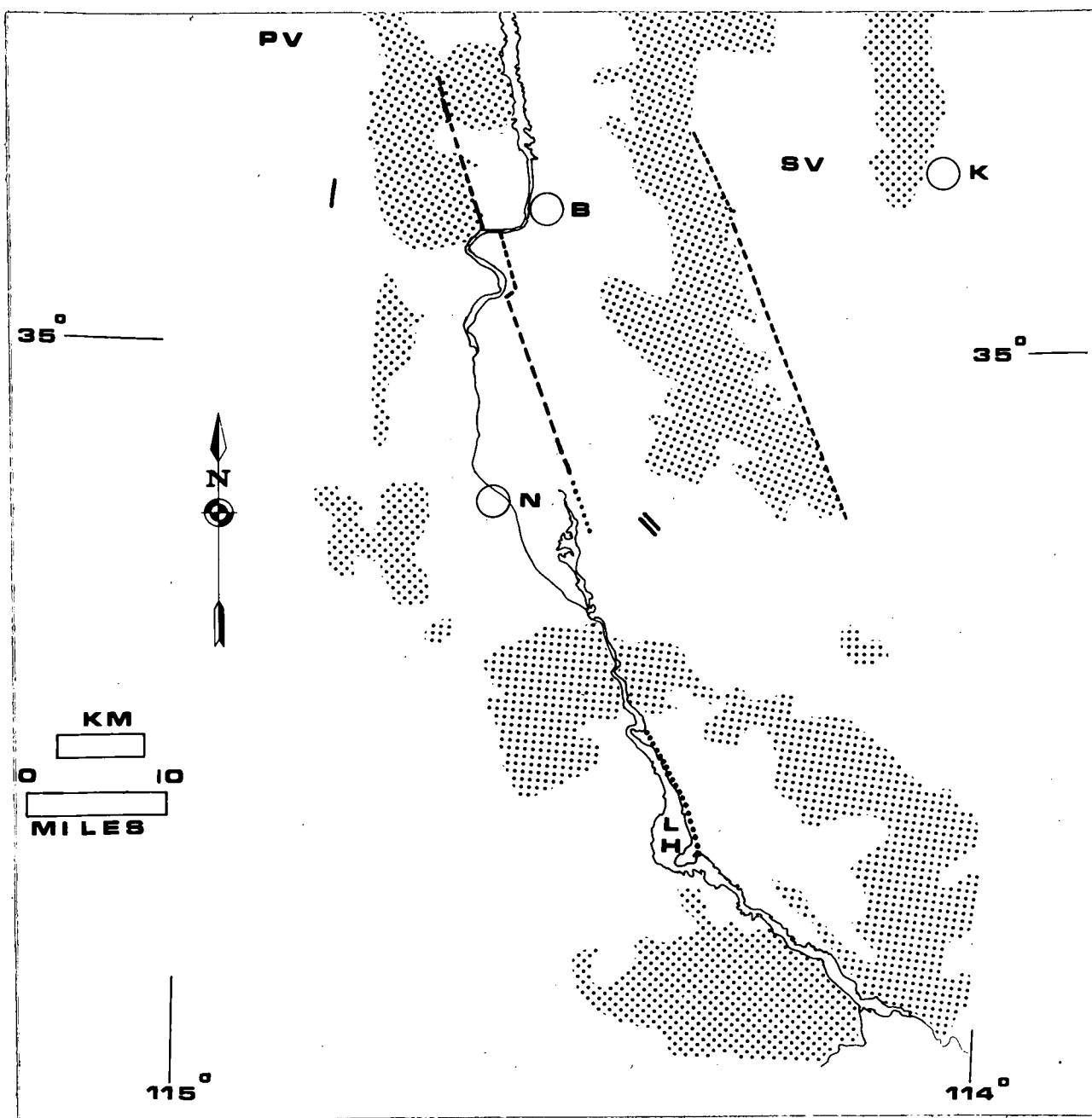


Figure 2 Previously unreported faults cutting alluvium in the southern half of area in Figure 1. Faults are dashed or dotted where indefinite or inferred. Bedrock areas are shaded. Location names as in Figure 1.

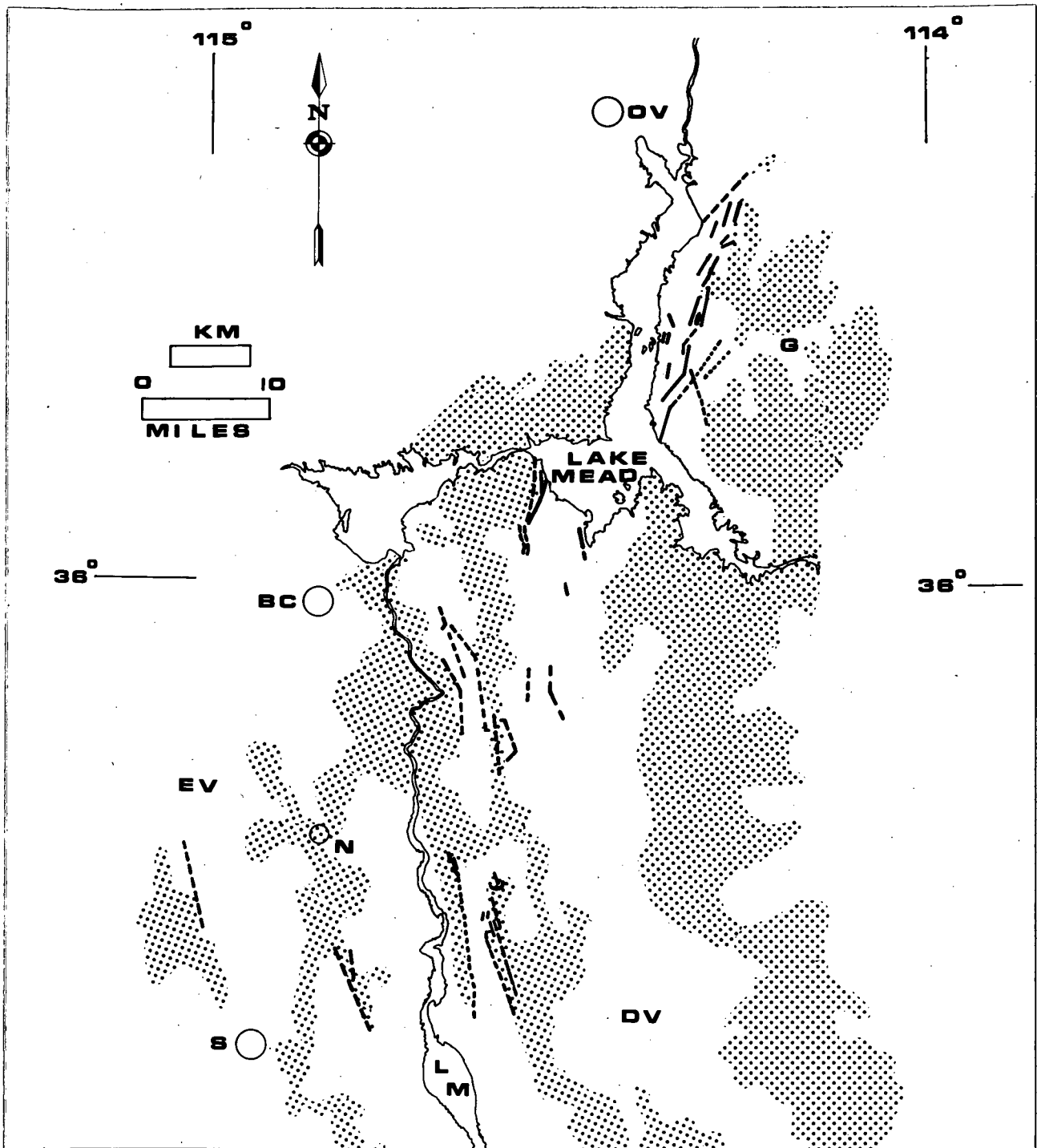


Figure 3 Previously unreported faults cutting alluvium in the northern half of area in Figure 1. Faults are dashed or dotted where indefinite or inferred. Bedrock areas are shaded. Location names as in Figure 1.